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EVALUATION AND SELECTION OF TEST SITES FOR BURMMS.(U)
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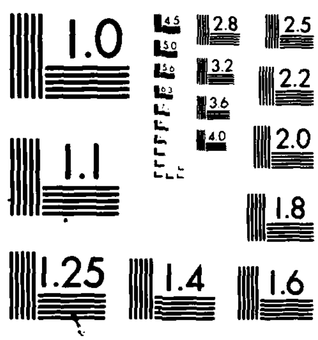
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Evaluation and Selection of Test Sites for BURMMS

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ABSTRACT

This report develops a procedure for selection, identification, and evaluation of test sites to be used in the development of BURMMS (Buried Mine Minehunting System). Potential test sites are evaluated and ranked by this procedure.

Panama City, Florida, Norfolk, Virginia, and New Orleans, Louisiana, are proposed as the primary BURMMS test sites.

The site selection rationale is based on three categories of test site attributes: (1) environmental parameters of the bottom that influence mine burial prediction; (2) physical setting at the test sites in which operations will be performed; and (3) logistical aspects of utilizing the test sites.

Selection factors include:

- Environmental Characteristics
  - impact burial
  - post-impact burial
  - range of environments
  - available historic environmental data and knowledge
- Physical Setting
  - sea conditions
  - climate
  - interfering activities
  - test site size
- Logistic Aspects
  - proximity of naval installations
  - quality of shore support
  - proximity to BURMMS centers
  - related activities at test sites

The principal environmental parameters considered are those that affect impact and post-impact mine burial. These parameters are sediment input, current energy, and bottom composition. On this basis, many river-estuary systems adjacent to open coasts provide a suitable range of conditions for each burial mode. However, carbonate and glacial marine environments present significant compositional variation from typical bottom types.

Nine potential test sites are evaluated and assigned scores for each selection factor. The totals of the site scores serve to rank the test sites. On this basis, the test sites fall into three groups: (1) most desirable: Panama City, Florida, Norfolk, Virginia, New Orleans, Louisiana; (2) desirable: Gulfport, Mississippi, Kaneohe Bay, Hawaii, the Washington Test Ranges; and (3) less desirable: Dahlgren, Virginia, New England, and Florida Bay, Florida.

I. INTRODUCTION

This report is an effort to select test sites as an aid in the development of the Buried Mine Minehunting System (BURMMS) and particularly in the development of the environmental subsystem of BURMMS. The test sites are intended to be a field laboratory that provides controlled or measurable conditions similar to those in which BURMMS and its environmental subsystem are expected to operate. One or more of these sites will be required to evaluate the performance of potential BURMMS components, initially potential environmental sensors. This evaluation will be followed by tests of the substages in various developmental stages, and eventually by tests of the complete system. Because of the variety of work envisioned and the wide range of environments with which BURMMS is required to deal, more than a single test site is required.

The above assumptions serve as the basis for the approach taken in this report. The test site selection procedure has been arranged into three parts: (1) the desired characteristics of a test site are examined, and a series of site selection factors is formulated; (2) potential test sites are described and evaluated; (3) a quantification of test site selection is attempted by a ranking procedure.

II. SITE SELECTION FACTORS

Certain general characteristics are desired in a site where BURMMS will be tested. First, the site should permit impact and post-impact burial of mines, and the site should be environmentally understood well enough so that the general operation of the planned tests can be predictably established. Second, environmental conditions during the tests should normally be favorable, and interference of other activities, such as ship traffic, minimal. Third, the site should be easily accessible for the users and nearby shore support should be available.

A. RATIONALE OF TEST SITE SELECTION

Site selection is based on the major attributes required for testing of BURMMS. These include: (1) the environmental parameters of the bottom that determine mine burial and the performance of mines and mine detection systems; (2) the physical setting in which operations will be carried out at the test sites; and (3) the logistical aspects of employing the site for development and testing of the environmental subsystem, and the BURMMS system itself. Because coastal and intracoastal shallow-water environments generally exhibit considerable variability of bottom types, any number of sites could meet the basic environmental requirements for testing BURMMS. Clearly, some sites offer greater benefits than others and can be identified and evaluated. However, from an environmental standpoint, test site selection is not so much an exercise in searching for a suitable environment, as it is recognizing the benefits and limitations of a group of sites. The physical and logistical aspects of utilizing a site provide a major constraint on site selection. Even so, a large number of potential sites remains for consideration. Depending on which logistical and environmental considerations take precedence for a particular aspect of BURMMS testing, the desirability of any site may be expected to change. Hence, test site selection is essentially subjective and is based on judgment of perceived needs and familiarity by the participants, in addition to a comparison of site characteristics.

B. ENVIRONMENTAL PARAMETERS

The number of environments in which BURMMS should be tested appears to be quite large. However, the following analysis shows that most environments have strong similarities with respect to BURMMS. A small group of basic characteristics can therefore be identified.

1. Analysis of Shallow-Water Environments. The areas in which BURMMS is expected to operate are essentially all coastal shallow-water environments from moderate-depth continental shelves landward, including nearshore waters, straits, passages, bays and deltas, to intracoastal areas such as lagoons, estuaries, river mouths and channels. Coastal areas have a high variability in bottom character, and a complete range of conditions is implied by this list of environments. Fortunately, each environment does not have to be evaluated separately with respect to BURMMS tests. There is considerable overlap in the range of parameters that characterize these environments, and they may be classified to show that most bottom conditions likely to be encountered by BURMMS can be found to a sufficient extent in a small number of areas.

Bottom character in shallow-water areas can be treated as a result of the effect of two variables: (1) net sediment input into an area, principally by rivers, glaciers, organisms or from adjacent waters; and (2) the energy regime, principally currents and waves, of the area. Figure 1 illustrates these relationships and relates them to mine burial. Low-energy regimes are characterized by mud regardless of sediment input. High sediment input is characteristic of active areas such as deltas and some estuaries and channels, whereas relatively low sediment input is associated with lagoons, estuaries and depressions on the continental shelf. High-energy regimes show greater variability. When sediment input is high, mud and sand may both occur, but as sediment input decreases, the regime becomes sandy and eventually erosive, in which case a hard substrate may be exposed. The latter case is typical of open coasts and shelves; the former is characteristic of deltas, estuary mouths, inlets, and some channels. Impact burial, which occurs in weak sediment, prevails in low energy regimes and with high sediment input. Post-impact burial requires a high energy regime, with sediment input being a secondary factor. The range of conditions illustrated by the diagram can be met to a substantial degree by a number of coastal areas. Many larger estuaries and river mouths contain a range of subenvironments that effectively covers the field of the diagram. Thus, only a small number of sites is required to reproduce, in general, the working environment of BURMMS.

One aspect not addressed above is the effect of sediment composition on BURMMS performance. In most cases this aspect is minor because most sediments are terrigenous and fluvial or glaciofluvial. The vast majority of low strength muds, for instance, is predominantly aluminosilicate clays; sands and silts are typically silica with greater or lesser admixtures of other silicates. Considerable variation in the physical behavior of clays does occur, but is not known well enough areally for site selection.

Two potentially distinct sediment types are carbonates and glacial deposits. Carbonates are biogenic and are found at low latitudes where other sediment input is low, particularly on islands and banks. Both impact and post-impact burial can be experienced in carbonates, since they may occur as soft muds or current-winnowed sands, in addition to reefs. Glacial sediment, common at high latitudes, though terrigenous, can occur as a distinct sediment type in that it is poorly sorted and may contain even large boulders in a fine-grained matrix. In the case of both carbonate and glacial sediment types, if BURMMS performance is suspected to be affected, an appropriate test site should be selected.

2. Environmental Characteristics of Test Sites. The principal selection factors for a BURMMS test site are environmental since these determine the operational settings of the system. These selection factors are (1) likelihood of impact burial of mines; (2) likelihood of post-impact burial of mines; (3) range of environmental conditions at the test site; and (4) the state of environmental knowledge of the area.

(a) Impact Burial. Impact burial requires a bottom of relatively low bearing strength. Such bottoms are usually mud or sandy mud. In coastal areas, low strength muds are the result of rapid deposition, and they are common, though often patchy in distribution. Very low density, or soupy muds are associated with channels in estuaries, turbidity maxima, and lower reaches of rivers. Impact burial is, of necessity, the primary requirement in site selection, but is not a constraining one because it is met, to some extent, in most locations.

(b) Post-Impact Burial. Sediment transport by waves as well as by tidal, coastal and river currents is the major cause of post-impact burial. Since it is a dynamic, time-dependent process, a requirement for post-impact burial introduces uncertainties in a testing scheme. Therefore, sites with pronounced sediment transport are preferred. The major post-impact burial environments are tide-dominated sand wave and sand ridge fields of large estuary mouths and restricted continental shelves, wave-dominated nearshore sand bars and ridges of high-energy open coasts, tide-dominated estuaries and particularly dredged channels within estuaries, and river channels. Sand-wave fields and open coasts are sandy, whereas estuarine and riverine post-impact burial environments are predominantly muddy, but may be sandy.

(c) Range of Environments. It is desirable to have a large variety of environments represented at a single test site. Fewer test sites would be required and more comprehensive testing would be possible. The significant environments for BURMMS have been discussed above. Ideally, a test site should contain the following environments: (1) a range of low-strength muds; (2) a sand wave field; (3) a high-energy open coast; (4) dredged shipping channels within an estuary; (5) a river channel, (6) a carbonate environment; (7) a glacial environment; (8) variable water depths, and (9) probably a bottom littered with manmade objects. This list is not comprehensive, and the need for specific conditions may change in the course of testing. It is apparent that all conditions cannot be found at a single site but that some sites could provide a majority of them.

(d) Environmental Data. To be useful, a test site must be well understood environmentally. Areas in which comphrehensive scientific and technical studies have been made are preferred because the environmental effects on the planned tests can be better predicted. Previous studies may also reduce the required environmental investigations of the test sites. However, data from previous studies are rarely sufficient or appropriate as the environmental background for comprehensive testing operations and, therefore, cannot usually be substituted for on-site environmental studies.

C. PHYSICAL SETTING

Environmental factors that contribute to the overall characteristics of a site, but which do not have a direct relation to performance of BURMMS, fall into the category of physical setting. These factors characterize site conditions that could adversely affect the performance of BURMMS testing. These factors are: sea conditions; (2) climate; (3) interfering activities, and (4) test site size.

1. <u>Sea Conditions.</u> Sea state, breakers, and extreme currents can present formidable obstacles to technical operations performed from small vessels. Coastal work invariably involves shallow draft vessels of limited stability, and considerable time may be lost to weather delays. Test sites where there is high frequency of severe conditions should, therefore, be avoided. However, some coastal environments, notably sand waves and high energy nearshore areas, are necessarily the result of extreme conditions, and a test site cannot be rejected simply because extreme conditions do occur there.

2. <u>Climate.</u> Climate is a factor related to sea conditions but one that can affect BURMMS testing on a seasonal basis. Areas that experience long, cold winters and a high frequency of low pressure cells are unfavorable because testing cannot be scheduled on a year-round basis. In general, climatic favorability decreases at higher latitudes.

3. <u>Interfering Activites.</u> BURMMS testing can be affected by other activities within the test site. Interference will depend on the nature and extent of the activity. Interference may range from nuisance and partial disruption to temporary or total suspension of testing. Typical interfering activities to be considered are ship traffic, fishing, pleasure boating, vandalism, construction, dredging, and military operations.

4. <u>Size of Test Site.</u> A final consideration of setting is the adequacy of the test site size. Whereas some point-type tests may require a small area, other tests may be expected to require larger areas, up to the size necessary for survey or mine-hunting type operations. Small, restricted areas are normally unfavorable, particularly if the risk of interfering activities is high. On the other hand, test site areas that are very large are also somewhat less favorable because excessive boat travel times could be required.

D. LOGISTIC ASPECTS

Logistic aspects concern the accessibility and efficient use of the test site. They include proximity of naval installations, proximity of shore support, proximity to centers of BURMMS activities, and overlap with related work in the area.

1. <u>Proximity of naval installations.</u> A naval installation in the vicinity of the test site is almost essential if more than casual or supplementary efforts are intended. A naval installation can provide security and administrative aspects, in addition to providing cost effective and often unique shore support. However, extensive shore support may not be feasible from every naval installation, and support from other military branches or the civilian area will be required.

2. <u>Quality of Shore Support.</u> Extensive supporting facilities at the test site will expedite all operations. Of particular importance is the availability of one or more boats in the 30-80 foot range, and helicopter air support. Also required are docking and staging areas. An existing operational nearshore precision navigation system that covers the test site is desirable and could be essential during tests of the full-up BURMMS system in the out years.

3. <u>Proximity to BURMMS Centers.</u> BURMMS environmental support activity is centered around Naval Coastal Systems Center (NCSC) at Panama City, Florida,

Naval Ocean Research and Development Activity (NORDA) and Naval Oceanographic Office (NAVOCEANO), located at the National Space Technology Laboratories (NSTL) at Bay St. Louis, Mississippi, and Louisiana State University, Baton Rouge, Louisiana. Test site proximity to these locations is not essential but is clearly desirable from the standpoint of convenience and familiarity. For this reason, a "home base" test site is highly desirable. Extremely remote sites, on the other hand, must possess significant advantages in other selection factors to make them attractive.

4. Related Activities at Test Sites. More effective utilization of test sites may result when related activities are being performed there. Data collected by one activity may benefit the other and may provide information that might otherwise not be obtained. Such activities may be of a long-term environmental monitoring type, such as weather, tides, current and wave data, or a part of specific projects by the Navy, government agencies or academic institutions.

III. TEST SITE DESCRIPTIONS

This section describes a series of proposed test sites. The choice of these sites, in addition to being grounded in significant characteristics required for BURMMS testing, is based on expressed interest and experience of BURMMS participants, on a perception of related activities at the sites, and on an attempt to provide coverage of most environments of potential significance to BURMMS. It must be made clear that these sites do not represent a complete survey of all potential test sites; other sites of generally equal merit could be produced. However, the sites do represent a profile of the types of areas that could be utilized, and they represent the spectrum of environments in which BURMMS is likely to be employed. The site descriptions are presented in a format of (1) geographic description; (2) salient aspects of the three categories of selection factors, i.e., environmental parameters, physical setting and logistic aspects; and (3) a statement of the major advantages and disadvantages of the site. A list of potential test sites and a summary of their environments is presented in Table 1. Major advantages and disadvantages are summarized in Table 2. Test site descriptions follow in alphabetical order.

A. DAHLGREN, VIRGINIA

The Dahlgren test site comprises a section of the central Potomac River Estuary. It is about 15 miles long and 5 miles wide. However, portions of the site are quite shallow, and the effective usable area is considerably less. Sediments are terrigenous muds and sands; moderate tidal flow and low-energy waves are the primary depositional and erosional agents. Salinity is quite low. A dredged navigation channel passes through the site.

Environmental characteristics: The Dahlgren site should be well-suited for impact burial in muds and sandy muds. However, because wave and current magnitudes are too low the site does not appear to be suited for post-impact burial, except perhaps for protected-water siltation conditions. Therefore, Dahlgren is essentially a single-environment site. Environmental data on the Potomac River Estuary and the site itself are scarce.

Physical setting: Extreme sea conditions are not a problem at the Dahlgren site. Climate is acceptable except for the winter months, when occasional freezing-over of the estuary may be expected and frequent storms may disrupt field work efforts. Interference by other activities should not be a problem. Size of the site is satisfactory, but very shallow water may restrict the extent of the operating environment.

Logistic aspects: The Dahlgren site is adjacent to the Naval Surface Weapons Center (NSWC), which should provide adequate support for testing operations. The site is at some distance from BURMMS activities on the Gulf Coast, but is near Washington, D. C., where a number of activities are located from which support could be drawn. Information resulting from non-BURMMS activities conducted at the site by NSWC should prove helpful to BURMMS testing.

Advantages: The Dahlgren site is a good estuarine-riverine impact burial environment. Shore facilities and support should be quite good.

Disadvantages: Dahlgren is a single-environment site and very shoal water predominates. Environmental background work appears to be sketchy.

B. FLORIDA BAY

Florida Bay, located between the Florida peninsula and the Florida Keys, contains the most extensive occurrence of carbonate muds on the continental United States. The site is proposed as a model carbonate setting, which could be a significant BURMMS operating environment, although probably one of secondary importance. Since Kaneohe Bay, Hawaii, is also largely a carbonate environment, measurements and tests related to this bottom type could probably be performed there as well, although the Florida Bay site is more extensive and offers a greater variety of conditions. Florida Bay deepens to the west from an extremely shallow patch reef environment to a shallow shelf with a depth of about 30 meters. Most of the bay is floored by soft muds, but sandy bottoms do exist to the west and the north. To the south, the Florida Keys offer reef and associated tidal channel and lagoonal environments.

Environmental characteristics: Impact burial should be achievable in a variety of water depths within Florida Bay. In shallow water around the Keys, conditions of small, hard, reefal limestone patches and soft, carbonate bottoms are abundant. Post-impact burial conditions are probably limited, although some carbonate sand and sand wave environments, produced by moderate tidal currents around the keys, may be found. The area appears to be moderately well, but not extensively, studied.

Physical setting: Year-round operation is possible at the Florida Bay site. Wave and current conditions are moderate, although western Florida Bay should be considered as an open shelf of moderate wave energy. The potential area of the site is large, though possibly too large. Interfering activities should not be a problem.

Logistic aspects: Access to the Florida Bay site would have to be from the Keys; hence shore support would be weaker than at most sites. The naval facility at Key West could be utilized. Proximity to BURMMS centers is fair. Related activities of use to BURMMS are probably minimal.

Advantages: Florida Bay is an excellent site for investigations within a carbonate environment on the continental United States.

Disadvantages: Access to the site and shore support are limited, as are the range of environments.

C. GULFPORT, MISSISSIPPI

The Gulfport, Mississippi, site is of interest because of its convenient location to BURMMS centers, and because it is being investigated by several other activities. The Gulfport site is a lagoonal-barrier island environment, with moderate to low wave energy, moderate tidal action, and muddy to sandy bottoms. It is similar to the Panama City site in general characteristics, but is more open and considerably more muddy. A sound about 15 km wide and 3-5 m deep separates the coast from the barrier islands, which face the Gulf of Mexico and are divided by tidal inlets and associated bars. The Gulfport shipping channel and the Intracoastal Waterway traverse the site.

Environmental characteristics: The Gulfport site should provide adequate impact burial. Also, scour or possible sand wave migration around the tidal inlets may allow for post-impact burial at some locations. Environmental data for the site is sparse but appears to be accumulating.

Physical setting: Most of the site is in protected water, and wave conditions should generally be low. Tidal currents are moderate. Working conditions are favorable year-round, though marginal in winter. Interfering activities, though generally low except in the heavily travelled Intracoastal Waterway/Gulfport Shipping Channel and during seasonally intense shrimp trawling, could be a problem. Test site size is adequate but not too extensive.

Logistic aspects: Shore support at the Gulfport site should be satisfactory. Relevant naval activities in the vicinity are NORDA, NAVOCEANO, and the Naval Construction Battallion Center. Both NORDA and NAVOCEANO have begun activities in the Gulfport site and are expected to continue them in the future.

Advantages: The Gulfport site offers favorable impact burial conditions coupled with a convenient operational setting.

Disadvantages: The site is not well-investigated.

D. KANEOHE BAY, HAWAII

Kaneohe Bay is a small, compound, estuary lagoon situated on the northeast side of Oahu. It is approximately 14 km long and 7 km wide. A deep and a shallow barrier reef separate the lagoon from the extremely narrow island shelf, and a fringing reef follows the shore of the bay. Muds floor the lagoon, whereas the fore-reef area and channels are sandy. Sediments near the shore are terrigenous, but most sediments are predominantly calcareous. The floor of Kaneohe Bay has been modified considerably by dredging; excavations and spoil areas occur throughout the bay. Kaneohe Bay is thus primarily a protected, soft bottom environment with mixed calcareous-terrigenous sediment.

Environmental characteristics: Impact burial should be readily achievable in the soft muds of the lagoon. The post-impact burial environment appears to be marginal because of only moderate tidal action. However, the fore-reef and channel mouth areas exposed to surf and wave surge are potential high-energy, post-impact burial environments. The range of test site environments is thus somewhat limited. Kaneohe Bay has been well-studied because of environmental problems arising from its urban setting and because of previous naval work, and its general characteristics are well-understood.

Physical setting: Unfavorable working conditions due to weather or climate are at a minimum and year-round work is possible. The overall site is relatively small, and congestion from commercial and military activities may be expected.

Logistic aspects: A Naval Undersea Center Laboratory facility and the Kaneohe Marine Corps Air Station are located on Mokapu Peninsula, at the southeast end of the bay. Although the site is remote from BURMMS centers, shore facilities and support should be excellent. Some work similar to BURMMS is performed at the Naval Undersea Center. The University of Hawaii, which has a Marine Laboratory on Mokuoloe Island, oversees a continuing effort of environmental studies of the bay.

Advantages: Kaneohe Bay provides an excellent setting for impact burial-related studies. It is primarily a carbonate environment. It is well-understood and ample shore support is available.

Disadvantages: The site is somewhat small and congested and is remote from centers of BURMMS activity. The range of test site environments is limited; post-impact burial sites are probably of marginal utility.

E. NEW ENGLAND

A site on the New England coast is considered here in order to include the glacial-marine bottom environment in a survey of potentially significant BURMMS operating environments. Such a site would be either in the inner continental shelf waters of the New Hampshire-Maine coast or the western border of the Gulf of Maine. The Gulf of Maine is a complex, eroded continental shelf that was shaped by fluvial erosion and glacial scour. It has an irregular relief composed of a number of small basins, channels and irregular highs. Recent muds fill the basins; the highs are bedrock outcrops, often only thinly veneered with either poorly sorted glacial drift, composed of varying mixtures of clay to boulder-sized sediments, or current-winnowed sands. Modern fluvial sands and muds are more prevalent toward the coast, but even here the combination of glacial drift, muddy lows, and rock outcrops persists. The glacial marine environment thus displays bottom characteristics not found in other environments, which may affect BURMMS performance. The New England coast is the most accessible glacial marine environment in the United States, although the Alaskan coast is another alternative.

Environmental characteristics: Impact burial in the glacial marine environment is restricted to muddy deposits in the lows. Typical estuarine or riverine environments do, of course, exist adjacent to glacial marine shelf environments, but are not the primary consideration for this site. Post-impact burial conditions would be produced by tidal current transport of sands, and post-impact burial is probable at this site. The Gulf of Maine and adjacent coastal areas are moderately well-studied, with the exception of well-studied estuarine and coastal areas.

Physical setting: The New England site is on the open continental shelf and is therefore unprotected. Unfavorable sea conditions, high waves, wind, and fog can be expected frequently, and operations would be practical only during summer. The extent of the site would be adequate though perhaps too large; depths are around the maximum at which BURMMS would operate.

Logistic aspects: The New England site is somewhat distant from centers of BURMMS activity. However, shore support, including naval facilities, should be satisfactory in the Portland, Maine, area or perhaps at Portsmouth, New Hampshire.

Advantages: The New England site provides a glacial-marine environment in the vicinity of good shore facilities.

Disadvantages: The site is in relatively deep, open water and only summer operations are feasible. It is a single-environment site.

F. NEW ORLEANS, LOUISIANA

The New Orleans site includes the Mississippi River from New Orleans to its mouths at the delta front, a channel length of about 150 km, and the bays that border the major passes, particularly East Bay between South and Southwest Passes. The site is essentially a riverine-deltaic environment with muddy bottoms and substantial current in the channel. The river channel offers a protected environment, whereas the Bays are open to the Gulf of Mexico and exposed to moderate wave energy.

Environmental characteristics: Since most of the site is underlain by soft muds, it is an ideal impact burial environment. Sand is also found on the channel floor, and post-impact burial by scour and sedimentation in both sandy and silty sediments is to be expected. The bays provide a soft-bottom, low-current environment that is unusual and advantageous in having numerous pipelines, underwater structures, and objects against which BURMMS performance may be tested. The Mississippi Delta is a well-studied environment, and data from numerous sources should be available.

Physical setting: The New Orleans site should have generally favorable sea conditions in open water with a wave climate of moderate energy. Currents in the channel may be quite strong and could make operations difficult. The channel is also extremely congested with ship traffic, and this factor could severely limit any extensive testing. The operating areas are of sufficient size but may, in fact, be too extensive for a single staging area.

Logistic aspects: Adequate shore support should be available in New Orleans and at the Naval Support Activity in Algiers, Louisiana. However, these locations are distant from the Mississippi River mouth and may not be practical. The New Orleans site is conveniently close to locations of BURMMS activity, including Louisiana State University (LSU), NORDA, NAVOCEANO, and NCSC. The Mississippi River channel and delta are under frequent investigation by the Corps of Engineers and LSU, and these activities may provide input to BURMMS operations at this site.

Advantages: The New Orleans site offers an ideal and well-studied river and delta environment with soft bottoms and sandy bottoms in which both impact and post-impact burial can be evaluated.

Disadvantages: The site is congested. Shore support and long transport distances could be a problem.

G. NORFOLK, VIRGINIA

The Norfolk, Virginia, site is large, geographically complex, and encompasses a number of subsites. It includes the Chesapeake Bay entrance and lowermost Chesapeake Bay, Hampton Roads, and the nearshore continental shelf and coastal area. Willoughby Bay and Little Creek Harbor are adjacent smaller locations of interest, and the lower reaches of the James River, though presently not considered part of the site, could be of use. Several environments are represented at the site. The nearshore shelf is a high-energy, wave-dominated sandy coastal environment. The Chesapeake Bay Entrance is tide-dominated; sand waves and shoals predominate in the northern part, muddy sands in the southern part. Two major shipping channels traverse the bay entrance and lower bay. The Baltimore, or Chesapeake Channel runs northwestward through the central section. It is largely natural. Thimble Shoal Channel lies in the southern portion of the lower bay, and runs westward into Hampton Roads. This channel is frequently dredged; it is subject to considerable sedimentation, probably due to strong tidal action. Little Creek Harbor and Willoughby Bay are protected-water areas with soft bottoms. Hampton Roads is the lower part of the James River estuary; a combination of strong tidal currents, channels, sand, shoals, and soft bottoms coexists there.

Environmental characteristics: Impact burial can be achieved within the bay south of Thimble Shoal Channel, at certain locations off Cape Henry at the bay entrance, in Willoughby Bay, in Little Creek Harbor, and probably within Hampton Roads. Softest bottoms are likely to be encountered in Little Creek Harbor and Willoughby Bay. Post-impact burial conditions are favorable in the sand wave fields of the bay entrance and on the inner shelf and beach areas south of the bay entrance. Tidal action around the bay mouth is strong, and wave exposure is to the open Atlantic. Post-impact burial conditions may also exist in Thimble Shoal Channel and Hampton Roads. As is evident from the preceding information, the Norfolk site is characterized by a fairly complete range of environments. Knowledge of the area is high, though not complete. Numerous studies of various aspects and locations exist, but comprehensive knowledge is lacking, due to the size and complexity of the area, particularly with respect to bottom characteristics, sediment transport and tidal action.

Physical setting: Sea conditions in Chesapeake Bay and its entrance may be severe, especially when produced by northwest and northeast winds and magnified by tidal currents. Other areas are well-protected and pose no weather problems. Year-round work is possible at the Norfolk site, although it may be marginal or unproductive in winter due to storms and occasional extended cold periods. Considerable interfering activity occurs. Commercial ship traffic is heavy within channels, and the Hampton Roads anchorages. Commercial fishing, including crabbing, occurs throughout the lower bay. Naval activities are staged in the bay off Little Creek Harbor, which itself is somewhat congested. Willoughby Bay and the Chesapeake Bay south of Thimble Shoal Channel are infested by pleasure boaters. This congestion makes careful planning of any tests essential. However, the magnitude of the entire site and the possibility of multiple test locations reduces the interference problem.

Logistic aspects: The Norfolk site is a location of major naval activity. Installations include the Little Creek Amphibious Base, the Norfolk Naval Station, and two Naval Air Stations. A military reservation at Dam Neck, Virginia, includes an adjoining offshore bombing range in the open Atlantic. Sources of shore support thus appear sufficient. Besides the Navy, U. S. Army Corps of Engineers, National Oceanic and Atmospheric Administration, and Old Dominion University operate survey and research vessels in the area and may provide shore support. Proximity to BURMMS activities is moderate, but the site is centrally located on the Atlantic seaboard. Although there are no activities specifically related to BURMMS, considerable research, surveying, and monitoring activities by the abovementioned organizations take place in the area.

Advantages: The Norfolk test site provides an extensive range of environments for impact and post-impact burial settings. Logistics are excellent since numerous military and civilian shore support activities are available. The area is well-studied, and ongoing environmental work of possible supporting value is carried out by several organizations.

Disadvantages: The Chesapeake Bay entrance and inner shelf portions of the site are somewhat large and are subject to extreme sea conditions. Congestion is a problem in channels and protected areas.

H. PANAMA CITY, FLORIDA

The Panama City, Florida, site offers a complex of shallow continental shelf, lagoonal, and estuarine environments. The continental shelf on the Gulf of Mexico has a gently sloping, relatively featureless, sandy bottom. The nearshore environment is sandy and is exposed to moderate wave energy. The St. Andrews Bay system is about 8 km deep and 15 km wide, but typical shore-to-shore widths are around 3 km. A natural and a manmade inlet connect St. Andrews Bay to the Gulf of Mexico. Tidal currents are moderate, but are of sufficient magnitude to effect small-scale migrating sand waves. Currents in and around the inlets can be more energetic. Sandy and soft, muddy terrigenous sediments coexist in St. Andrews Bay.

Environmental characteristics: Impact burial can be achieved at a number of quiet-water, soft bottom locations within St. Andrews Bay. The site is also somewhat favorable for post-impact burial by sand wave and sediment transportation in the central and inlet-associated areas. The continental shelf area is probably not conducive to post-impact burial, except in the extreme nearshore area and surf zone. The Panama City site has a sufficient range of environments for mine-burial work, but they appear to be of a moderate nature. Considerable environmental information has been amassed for this site, and it can be characterized as very well-studied.

Physical setting: Wave and current conditions in St. Andrews Bay are very favorable; it is a protected environment. The adjacent continental shelf also presents a moderate environment, and interruptions due to unfavorable waves and swell should be less than on most open coasts. Climate is favorable, with essentially year-round working conditions, although periods of unfavorable weather will occur in winter. Interference from other activities should not be significant. The extent of the site is moderate but adequate, although this consideration, in combination with moderate environmental conditions and relatively shallow depths within the bay, might restrict the range of conditions to be examined for BURMMS.

Logistic aspects: Panama City is the site of the Naval Coastal Systems Center, a key BURMMS activity. BURMMS project work has been performed there, and NCSC holds considerable expertise on the project. In addition, a number of related mine warfare activities are performed by the laboratory. Shore support is excellent, and a computerized, shorebased tracking system that extends over the nearshore waters of the Gulf of Mexico, the presence of a test rail in St. Andrews Bay for underwater instrumentation, and availability of boat and helicopter support are of note.

Advantages: The Panama City site provides excellent logistics and support. It is a well-studied, multi-environment site.

Disadvantages: The range of environmental conditions may be too moderate, especially for post-impact burial.

I. WASHINGTON TEST RANGES

Two separate areas are included in the Washington test ranges: (1) the Quinault Range, a sandy open-shelf environment off Westport, Washington; and (2) several locations in Puget Sound, a protected tidal-estuarine environment. Both are of interest, primarily because they offer extensive environmental documentation and are used for torpedo development work by the Naval Undersea Weapons and Engineering Station at Keyport, Washington, and by the Applied Physics Laboratory of the University of Washington.

Environmental characteristics: The Quinault Range presents environments not particularly favorable for BURMMS testing because (1) impact burial would not be expected in the sandy bottom; and (2) rapid burial by sediment transport is questionable in 60 m depths on the open shelf. Within Puget Sound, a variety of bottom types exists, and there are sufficient tidal currents to permit impact and post-impact burial. The respective sites are well-understood environmentally, and together provide a wide range of conditions.

Physical setting: Sea conditions at the Quinault Range are often severe, as this is a high-energy open shelf location, and operations could often be curtailed in winter. The inland waters of Puget Sound offer more favorable working conditions but would also be marginal in winter. Interfering activities should not be a problem. The Quinault Range is of adequate size; however, the two ranges within Puget Sound currently investigated are only about 1 km^2.

Logistic aspects: Shore support should be adequate at the Washington site. It is located at a major urban center, Seattle, and facilities are available from the University of Washington and several naval installations. The relevance of environmental work related to torpedo development activities is significant, and the area in general is well-studied. Location from BURMMS centers is remote.

Advantages: The Washington test ranges are well-researched, and Puget Sound should provide a variety of impact, and possibly post-impact burial environments. Shore facilities are good.

Disadvantages: Unfavorable weather and bottom conditions prevail at the Quinault Range.

IV. RANKING OF TEST SITES

In order to render the selection of the proposed BURMMS test sites more objective, especially to reduce some of the subjectivity in comparing the selection factors for each test site, a ranking procedure was developed. The procedure consists of assigning quality points to each site on the basis of each of the 12 site selection factors, and summing the points for each site to give a total score that serves as its rank among the other sites. Because the selection factors are evenly grouped into the categories of environmental characteristics, physical setting and logistic aspects, separate rankings for the 3 categories were made first, and then the scores combined for a comprehensive ranking. A range of five quality categories was employed; 5 = excellent, 4 = good, 3 = fair, 2 = marginal, 1 = doubtful. Initial attempts with smaller ranges did not give sufficient resolution in scores, and a greater range is not justified because of the inherent subjectivity in assigning values to the selection factors. Thus, the maximum score difference possible among sites with this procedure is 16 for each of the three categories and 48 for the total scores.

Tables 3, 4, and 5 show rankings for environmental characteristics, physical setting, and logistic aspects, respectively. Table 6 presents total rankings. It is of note that the score difference coefficient (achieved score difference divided by maximum possible score difference) is reasonably high for the three categories (0.5, 0.38, 0.69), but lower for the total ranking (0.31), indicating substantial differences among site characteristics, which, however, tend to cancel out one another in the final ranking to produce a quite homogeneous set of scores. In view of the subjectivity involved in assigning quality points to test site characteristics, sites with adjacent rankings should be considered of equal desirability if their scores are similar. With this caution in mind, Table 7 presents a final grouping of sites made by placing the sites, on the basis of similar scores, into three levels of desirability. This grouping, though it appears somewhat arbitrary, is largely the result of natural clustering of the test site scores presented in Table 6.

V. RECOMMENDATIONS

A. On the basis of environmental characteristics, physical setting and logistic aspects, Panama City, Florida, Norfolk, Virginia, and New Orleans, Louisiana, appear to have the best overall attributes required for BURMMS test sites and should be considered as prime candidates. Although their overall desirability is similar, each has characteristics that make it significantly different from the others.

B. The Gulfport, Mississippi, Kanehoe Bay, Hawaii, and the Washington test range sites, though less favorable, should also be considered desirable because of related activites occurring at these locations and because of the special characteristics of Kaneohe Bay.

C. Because many investigators (some of whom have specialized knowledge of one or more test sites and are located at various activities) are participating in BURMMS development, more than a single test site will be desirable. The range of potential BURMMS operating environments also dictates that more than one site be employed.

D. Panama City, Florida, Norfolk, Virginia, and New Orleans, Louisiana should be employed as the primary BURMMS test sites. However, changes in BURMMS needs and knowledge gained by investigators may cause other sites to become desirable. Therefore, the use of subsidiary sites whose merits become apparent in the future should not be ruled out.

E. For the primary BURMMS sites, test ranges should be defined. These should include small (<1 km^2) as well as larger areas, so that opportunities for spot measurements are available, and intensive as well as extensive surveying techniques and developments can be examined.

F. Within the defined BURMMS test ranges, collection and compilation of existing environmental data should be performed. BURMMS environmental data/reference files will contain a significant portion of the available material, and any additional material should be incorporated into the files.

G. The defined BURMMS test ranges should be thoroughly characterized before extensive testing of BURMMS and its subsystems takes place. The ranges should be characterized by bathymetry, shallow seismic reflection, side-scan sonar, sediment physical and geotechnical properties, wave and current regimes and other properties as required.

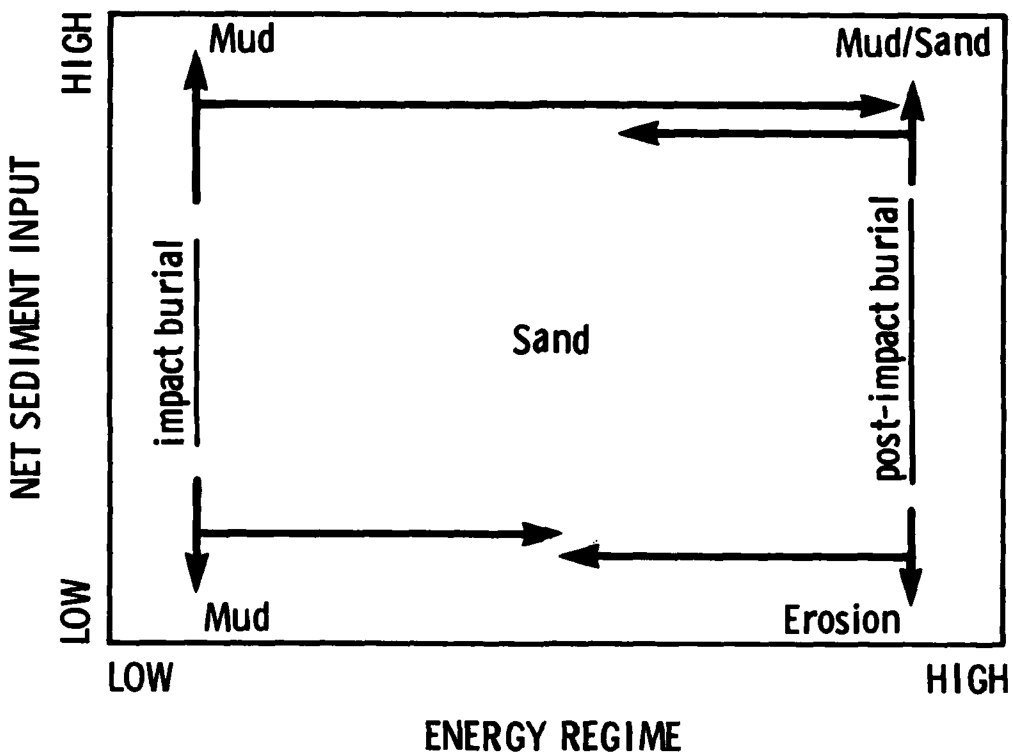

Figure 1. Schematic diagram relating environmental parameters to mine burial.

Table I. Test Site Environments Summary

TEST SITE	SEDIMENTARY ENVIRONMENTS	SEDIMENT SOURCE	BOTTOM TYPES
Dahlgren, Virginia	Fluvial/Estuarine	Fluvial	Mud/Sand
Florida Bay, Florida	Lagoonal/Continental Shelf	Biogenic	Carbonate, Mud, Sand, Reefs
Gulfport, Mississippi	Lagoonal/Continental Shelf	Fluvial	Mud/Sand
Kaneohe Bay, Hawaii	Lagoonal	Biogenic/ Volcanic	Mud/Carbonates
New England	Continental Shelf	Glacial	Rock/Gravel/Sand/Mud
New Orleans, Louisiana	Fluvial/Deltaic	Fluvial	Mud/Muddy Sand
Norfolk, Virginia	Estuarine/Tidal Continental Shelf/Surf	Fluvial	Sand/Muddy Sand
Panama City, Florida	Lagoonal/Continental Shelf/ Surf	Fluvial	Sand/Mud
Washington Test Ranges	Continental Shelf/ Estuarine	Fluvial	Sand/Mud

Table 2. Summary of Major Advantages/Disadvantages of Each Test Site

SITE	ADVANTAGES	DISADVANTAGES
Dahlgren, Virginia	Good estuary-river impact burial environment Good shore support	Single-environment site Limited background work
Florida Bay, Florida	Excellent carbonate environment on continental U.S.	Single-environment site Poor access and shore support
Gulfport, Mississippi	Good impact burial Convenient operational setting	Limited background work
Kaneohe Bay, Hawaii	Favorable for impact burial Carbonate environment (partial) Well studied Good shore support	Site is small and congested Range of environments is limited Remote location
New England	Glacial-marine environment Good shore support	Single-environment site Site located in deep, open water Summer operations only
New Orleans, Louisiana	Excellent river/delta environment Good impact burial site	Site is congested and operating distances may be large

Table 2. Summary of Major Advantages/Disadvantages of Each Test Site, (cont.)

SITE	ADVANTAGES	DISADVANTAGES
Norfolk, Virginia	Extensive range of environments Site is well-studied	Area is quite extensive Portions of the site are congested Sea conditions may be rough
Panama City, Florida	Excellent logistics and support Well-studied multi-environment site	Range of environmental conditions too limited
Washington Test Ranges	Sites are well-studied Range of environments Good shore support	Unfavorable weather and bottom types

Table 3. Test Site Rankings, Environmental Characteristics

	Impact Burial	Post-impact Burial	Range of Environments	Environmental Data	Subtotal Score	Ranking
New Orleans, Louisiana	5	5	4	4	18	1
Norfolk, Virginia	4	5	5	4	18	1
Washington Test Ranges	3	3	4	5	15	2
Kaneohe Bay, Hawaii	5	2	2	5	14	3
Panama City, Florida	4	3	3	4	14	3
Gulfport, Mississippi	5	3	4	2	14	3
New England	4	3	2	4	13	4
Florida Bay, Florida	5	2	3	2	12	5
Dahlgren, Virginia	5	2	1	2	10	6

Score difference coefficient: 8/16 = 0.5

5 - Excellent
4 - Good
3 - Fair
2 - Marginal
1 - Doubtful

Table 4. Test Site Rankings, Physical Setting

	Sea Conditions	Climate	Interfering Activities	Size of Site	Subtotal Score	Ranking
Gulfport, Mississippi	5	5	4	5	19	1
Panama City, Florida	5	5	5	4	19	1
Florida Bay, Florida	4	5	4	4	17	2
Dahlgren, Virginia	5	4	4	3	16	3
Kaneohe Bay, Hawaii	5	5	3	3	16	3
New Orleans, Louisiana	4	5	3	4	16	3
Norfolk, Virginia	4	4	3	5	16	3
Washington Test Ranges	3	3	4	4	14	4
New England	2	2	5	4	13	5

Score difference coefficient: 6/16 = 0.38

5 - Excellent
4 - Good
3 - Fair
2 - Marginal
1 - Doubtful

Table 5. Test Site Rankings, Lobistic Aspects

	Naval Installations	Shore Support	BURMMS Centers Proximity	Related Activities	Subtotal Score	Ranking
Panama City, Florida	5	5	5	5	20	1
Norfolk, Virginia	5	5	3	5	18	2
Washington Test Ranges	5	5	3	5	18	2
Dahlgren, Virginia	5	5	3	4	17	3
Kaneohe Bay, Hawaii	5	5	2	5	17	3
New Orleans, Louisiana	4	3	5	5	17	3
Gulfport, Mississippi	4	3	5	3	15	4
New England	4	5	3	3	15	4
Florida Bay, Florida	3	2	3	1	9	5

Score difference coefficient: 11/16 = 0.69

5 - Excellent
4 - Good
3 - Fair
2 - Marginal
1 - Doubtful

Table 6. Test Site Rankings, All Characteristics

	Environmental Parameters	Physical Setting	Logistic Aspects	Total Score	Ranking
Panama City, Florida	14	19	20	53	1
Norfolk, Virginia	18	16	18	52	2
New Orleans, Louisiana	18	16	17	51	3
Gulfport, Mississippi	14	19	15	48	4
Kaneohe Bay, Hawaii	14	16	17	47	5
Washington Test Ranges	15	14	18	47	5
Dahlgren, Virginia	10	16	17	43	6
New England	13	13	15	41	7
Florida Bay, Florida	12	17	9	38	8

Score difference coefficient: 15/48 = 0.31

5 - Excellent
4 - Good
3 - Fair
2 - Marginal
1 - Doubtful

Values presented are totals derived from Tables 3, 4, and 5.

Table 7. General Desirability of Proposed BURMMS Test Sites

	ENVIRONMENTAL CHARACTERISTICS	PHYSICAL SETTING	LOGISTIC ASPECTS	ALL CHARACTERISTICS
Most Desirable	New Orleans Norfolk	Gulfport Panama City	Panama City	New Orleans Norfolk Panama City
More Desirable	Gulfport Kaneohe Bay Panama City Washington	Dahlgren Florida Bay Kaneohe Bay New Orleans Norfolk	Dahlgren Gulfport Kaneohe Bay New England New Orleans Norfolk Washington	Gulfport Kaneohe Bay Washington
Less Desirable	Dahlgren Florida Bay New England	New England Washington	Florida Bay	Dahlgren Florida Bay New England

Listings are alphabetical within categories.

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This report develops a procedure for selection, identification, and evaluation of test sites to be used in the development of BURMMS (Buried Mine Minehunting System). Potential test sites are evaluated and ranked by this procedure.

Panama City, Florida, Norfolk, Virginia, and New Orleans, Louisiana, are proposed as the primary BURMMS test sites.

The site selection rationale is based on three categories of test site attributes: (1) environmental parameters of the bottom that influence mine

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) burial prediction; (2) physical setting at the test sites in which operations will be performed; and (3) logistical aspects of utilizing the test sites.

Selection factors include:

- o Environmental Characteristics
  - impact burial
  - post-impact burial
  - range of environments
  - available historic environmental data and knowledge
- o Physical Setting
  - sea conditions
  - climate
  - interfering activities
  - test site size
- o Logistic Aspects
  - proximity of naval installations
  - quality of shore support
  - proximity to BURMMS centers
  - related activities at test sites

The principal environmental parameters considered are those that affect impact and post-impact mine burial. These parameters are sediment input, current energy, and bottom composition. On this basis, many river-estuary systems adjacent to open coasts provide a suitable range of conditions for each burial mode. However, carbonate and glacial marine environments present significant compositional variation from typical bottom types.

Nine potential test sites are evaluated and assigned scores for each selection factor. The totals of the site scores serve to rank the test sites. On this basis, the test sites fall into three groups: (1) most desirable: Panama City, Florida, Norfolk, Virginia, New Orleans, Louisiana; (2) desirable: Gulfport, Mississippi, Kaneohe Bay, Hawaii, the Washington Test Ranges; and (3) less desirable: Dahlgren, Virginia, New England, and Florida Bay, Florida.

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